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RESEARCH PAPER P-445

STRATEGIC CHEMICAL WEAPONS IN INTERMEDIATE WAR (U

AD505050

Benson L. Tucker

November 1968

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION

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STRATEGIC CHEMICAL WEAPONS IN INTERMEDIATE WAR (U)

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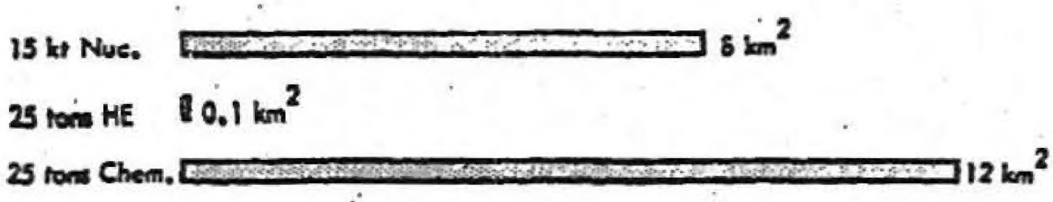
ABSTRACT

(C) B-52 chemical payloads, both lethal and nonlethal, can exceed in effective casualty area the 15-kt atomic bomb dropped on Hiroshima.



(C) Incapacitation periods from the use of chemical agents range from ten minutes (CS) to six weeks (T-agent). Areas may be denied to enemy habitation for an agent expenditure of about 3 g/m^2 per day.

(C) Specifically, chemical barriers might severely restrict infiltration and the use of the Ho Chi Minh Trail, Haiphong Harbor, and other Vietnamese jungle sanctuaries. Targets now exempt from HE attack might be neutralized by chemical incapacitating agents. In particular, attacks near South Vietnamese cities or villages should utilize incapacitating agents whenever possible to spare civilians.

(C) The cost to the United States of waging intermediate wars might be sharply reduced through the use of nonlethal chemicals without escalating the war, conferring a major advantage to the holder of air superiority, while the guerilla forces would be unable to reply in kind with any effectiveness. The use of nerve agents, on the other hand, would constitute an escalation of conventional war to a realm of lethality intermediate between HE and nuclear weapons. Kiloton effectiveness is achievable without crossing the nuclear bridge.

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I. INTRODUCTION

(U) Conventional weapons require vast tonnage to achieve decisive impact through air power. Intermediate wars further constrain air forces until raids exceeding in tonnage those which devastated Hamburg and Dresden merely seem to be plowing up jungles. Yet air superiority has been a major asymmetry in our favor in every intermediate war to date. What is needed is a munition more effective than TNT and napalm, and yet, neither as destructive as explosives nor as uncontrollable as BW. Nonlethality is a major weapon requirement in order to break the target constraints imposed by world opinion.

(U) The problem, then, translates into finding a weapon requiring substantially less weight than TNT or napalm to neutralize a target or an area, yet a weapon controllable enough to prevent the mass killings which occurred at Dresden and Tokyo or during the Black Plague. This problem definition suggests using some of the great variety of nonpropagating chemical agents.

(U) This report examines the use of chemical weapons in past conflicts, and their operational characteristics and assesses the feasibility of using such weapons for strategic interdiction missions in intermediate wars of the type being waged, for example, in Vietnam.

II. CHEMICAL AGENTS

(U) War gases--a misnomer in some cases since many are powdered solids--range from tear gases which are nearly harmless even in the target area, to nerve gases which may in rare instances remain lethal 30 or 40 km downwind.* The following list of agents begins with tear gases and continues through progressively more dangerous and more powerful compounds.

A. TEAR GASES

1. Chloroacetophenone (Usual Symbol: CN) [$C_6H_5COCH_2Cl$]

(U) This is the common police variety tear "gas," causing tearing when used in concentrations as low as 0.3 mg/m^3. It is really a solid and has to be heated or preground to make the smoky cloud seen in pictures of burning tear gas grenades. About 5 mg/m^3 is considered intolerable for more than five or ten minutes, although the victim is primarily harassed and vision-limited, rather than bereft of physical strength and coordination. Thus, strongly motivated people can still do damage while exposed to tear gas. Extreme doses--1000 mg/m^3 for ten minutes--might be fatal, but such concentrations are virtually unknown outdoors.

2. Bromobenzylcyanide (CA) [$C_6H_5CHBrCN$]

(U) The king of World War I lacrimators, CA, is a liquid less volatile than water, but volatile enough to produce a stinging vapor which severely irritates the eyes, nose, and throat, and which also causes acute pain in the forehead. Lethal concentrations, 400 to 1100 mg/m^3, are not obtainable in the field. As little as 0.3 mg/m^3 causes immediate tearing, and 3 mg/m^3 is considered incapacitating within ten minutes. Heavily splashed liquid persists one or two days under average weather conditions.

*Under prolonged inversion conditions.

(C) All of the foregoing have been used extensively (more than 6000 tons of arsenicals in World War I) with almost no fatalities. Three AEF deaths were ascribed to "arsine" gases, but these were probably due to the much more toxic ethyldichlorarsine, which will be discussed in a subsequent section on semilethal vesicant chemicals.

B. MENTAL INCAPACITATOR

(C) BZ, a glycolate derivative, causes a slowing of physical and mental activity, giddiness, disorientation, hallucinations, and occasional maniacal behavior. The central nervous system is functionally disturbed at all levels within 1 to 3 hours after a median dose of 112 to 170 mg-min/m^3, and incapacitation lasts 24 to 72 hours, or longer.

C. BIO-TOXIN (UC)

(C) Although UC is an inert chemical, it is somewhat different in that it is staph enterotoxin. Its effective dose is about 2 mg-min/m^3 resulting in nausea, fever, and abdominal pain. The onset time is 1 to 6 hours after exposure. The sickness lasts 8 to 16 hours. Since UC is odorless and the symptoms are delayed, it is unlikely that the victims would know they were in a UC cloud, resulting in a failure to mask or a premature unmasking. If an insidious nonlethal agent were required to circumvent masking, UC and BZ would be indicated.

D. VESICANT OR BLISTER GASES

1. Mustard Gas (HD) Dichlorethyl Sulfide: $S\begin{matrix} \nearrow C_2H_4Cl \\ \searrow C_2H_4Cl \end{matrix}$

(U) The most potent "king of the war gases" was a slowly evaporating liquid, dichlorethyl sulfide, which presented a triple threat to troops. At insidiously low concentrations, 1 or 2 mg/m^3, mustard vapor causes incapacitating conjunctivitis of the eyes at a dosage of about 200 mg-min/m^3.

(U) Raising the dosage to 1500 mg-min/m³ causes death by inhalation and near incapacitation by skin burns, for mustard penetrates and kills skin as well as mucous membranes. The third threat is the direct contact with the liquid, which produces gross blisters and ulceration that require many weeks to heal. No droplet is too small to cause blistering. The liquid easily penetrates leather and rubber boots, uniforms, and other equipment. The absorbed mustard may then contaminate a dugout by evaporation or contact if the splashed soldier seeks shelter therein. The cell destruction is rapid and initially painless. About 2 percent of the mustard casualties died of respiratory infection. In spite of mustard's outstanding percutaneous toxicity, the majority of mustard casualties were caused by vapor and not by the liquid contact--an important point for controlled casualty production.

2. T-Agent: Bis (β-chloroethylthioethyl) Ether

(U) This chemical relative of mustard is almost nonvolatile, so that it should not cause vapor casualties. Its vesicancy, however, is several times that of mustard, so well-defined contact-hazard areas can be expected where this agent is sprayed on the ground to form a barrier.

3. Nitrogen Mustard (HN-3): Tris (β-chloroethyl)amine: $N{<}(C_2H_4Cl)_3$

(U) This nitrogen analog of mustard is intermediate between mustard and T in volatility. HN-3 has vesicant and toxic properties very close to mustard's, but it is about ten times less detectable by odor.

E. LETHAL AGENTS

(U) When casualty dosages are also above the lethal threshold for susceptible individuals, it is manifestly impossible to lay down a 40 percent or 80 percent casualty dosage without killing a considerable fraction of the exposed population. It is, in practice,

even more difficult to avoid some lethality because concentration and exposure times cannot be closely controlled, so that some dosage contours may be ten or a hundred times others. Within this lethal category fall modern nerve gases and phosgene of World War I notoriety.

1. Phosgene (CG) Carbonyl Chloride

(U) Phosgene at initial exposure is only slightly irritant, attacking only the bronchi and lungs. Thus, the victim may not be driven from the area. Then follows a period of latency while edema is developing in the lungs over the next 2 to 20 hours. Discomfort may be slight, but fatal gray and blue asphyxia follows. The lethal dose is 3200 mg-min/m³, and the incapacitating dose is a dangerously close 1600 mg-min/m³.*

2. Sarin (GB): Methylisopropoxyfluoro-phosphine oxide

(C) World War II saw the Germans develop, but not use, agents which cause nerve functional breakdown from accumulated acetylcholine. Toxicity is almost two orders of magnitude greater than phosgene. The gas is almost odorless and swift in action. Detection and warning against surprise attack are thus extremely difficult. Incapacitating doses are listed as 35 mg-min/m³,** which is half the lethal dose, but only 5 mg-min/m³ may produce severe delayed toxic symptoms if repeated for 5 hours. This concentration may travel many miles downwind. Atropine with oxime is an effective antidote, raising the LD_{50} possibly to over 1000 mg-min/m³.

3. Percutaneous Nerve Agent VX [O-ethyl S-(2 diisopropylaminoethyl) methylphosphonothioate]

(S) Designed to circumvent gas masks, this liquid percutaneous nerve agent can kill at levels as low as 10 mg of liquid VX on the skin for 8 hours, or 200 mg for 1 hour. VX aerosols are fatal at only 45 mg-min/m³. Incapacitating doses are half the above, but a substantial number of these will die without prompt atropine antidotal treatment.

*German data suggest LD_{50} ~ 1000 mg-min/m³.

**For 15 liters/min breathing--mild activity.

III. DOSAGE ATTAINMENT AND EFFECTIVENESS

A. DOSAGES ATTAINABLE IN THE FIELD

(U) Clearly, a wide variety of agents have been developed, but specific dosages of particular agents and their conjugate diverse effects are valid only to the extent these dosages can be imposed in war situations. The German World War I rule of thumb of deploying 10 to 15 grams of agent per square meter was said to be effective, but the corresponding dosages are indeterminate without knowledge of the depth of the vapor layer and its persistency. Apparently, the depth was a number of meters because the needed effective concentration was much less than 15,000 mg/m^3. In reality, the chemical deployment processes were often so inefficient that only a small fraction of the agent reached the layer of air where the troops were. The remainder was caught in the soil or floated upward or was rapidly diluted by winds. Dissemination efficiencies varied considerably with the deployment technique and notoriously with the weather. However, the following examination of vapor and aerosol characteristics shows that reasonably controlled nonlethal chemical attacks are possible.

(U) First, one can note that vapor concentrations can never exceed the saturation level, and with normal outdoor circulation, vapor concentrations will be well below the saturation limit. Therefore, a possible approach to nonlethality is to use agents--such as CN and CA--of such low volatility that their saturated vapor is nonlethal within the expected exposure time. It is true that trapped or seriously wounded individuals might not be able to hasten their escape from a gas cloud, but their exposure time would still be limited to the evaporation time of the liquid or solid agent.

(U) Aerosols, however, may far exceed vapor saturation concentrations. Upper limits are set by coagulation and settling times. These upper limits are quite high. For instance, an aerosol of 10^8 1µ particles per cc corresponds to 52,000 mg/m^3. After five minutes, coagulation would reduce the number of particles to about 10^7, but there would be roughly 2µ in diameter and ten times as heavy and so maintain the concentration at 50,000 mg/m^3. Two micron particles have a fall rate of about 3 cm/min or 6 ft/hr. Further agglomeration would hasten the fallout to some extent, but a 20-ft-thick aerosol cloud carrying 50,000 mg/m^3 would have a mean life on the order of an hour. The total dose would then be ~ 3,000,000 mg-min/m^3--hardly a comforting upper limit.

(U) Fortunately, other physical factors can reduce aerosol persistence and dosage far below 3,000,000 mg-min/m^3. The most common factor is the transit time of a windblown cloud. Wind velocities are usually more than 100 ft/min, and so a cloud covering 10 acres would drift away in less than 7 minutes. Prentiss (Ref. 5) uses a typical exposure time of 10 minutes to determine lethal concentrations.

(U) As the cloud blows downwind, it is further weakened by dilution, fallout, and possibly by chemical reactions with a moist environment. If the cloud is lighter than ambient air and if lapse conditions prevail, it will tend to float upward, losing all effect on the ground. A British diffusion formula (Ref. 2) shows the following decline of phosgene concentration along the axis of the drifting cloud (Table 1).

TABLE 1 (U). PHOSGENE CLOUD CALCULATIONS

Downwind Distance, yd	Concentration, mg/m^3	Time of Passage, min	Dosage = Cxt
100	4800	0.5	2400
200	1700	0.55	930
500	330	0.7	230
1000	95	0.9	85
2000	20	1.2	24

(U) As Table 1 shows, this particular 250-lb phosgene bomb was self-limiting in downwind lethality to about 100 yd. If it had been a bomb with a high burster-to-agent ratio, even the initial, ground-zero dosage could have been reduced to sublethal levels.

(U) While diffusion theory works acceptably with continuous point sources (such as a cylinder of chlorine), it cannot predict the initial clouds from explosive munitions.

B. EXPLOSIVE CHEMICAL DISSEMINATION THEORY

(U) The initial gas cloud from a chemical shell with an HE burster is much larger than the gaseous volume of the vaporized agent and explosive. The contents of an exploding shell disassemble at a velocity, V_o, given by Gurney's formula below:

$$V_o = 7000 \sqrt{\frac{M_{ex}/M_{in}}{1+0.5\,\frac{M_{ex}}{M_{in}}}} \text{ ft/sec} \tag{1}$$

M_{ex} = mass of explosive (kg)

M_{in} = inert mass of the case and chemical (kg)

M_b = mass of bomb = $M_{ex} + M_{in}$ (in kg)

(U) Assuming the centrifugal bomb components "snowplow" and entrain the adjacent air and share the momentum implicit in the Gurney velocity, the velocity will be governed by conservation of momentum,

$$V = \frac{dR}{dt} = \frac{V_o \times M_b}{M_b + M_{air}} \tag{2}$$

(U) For times approaching cloud stabilization, the radial velocity will be small, meaning that $M_{air} \gg M_{bomb}$

$$\therefore \frac{dR}{dt} = \frac{V_o \times M_b}{M_{air}} \tag{3}$$

but

$$M_{air} = \frac{4}{3}\ (\pi\rho r^3) = (5r^3)\ (kg)$$

$$\frac{dR}{dt} = \frac{V_o \times M_b}{5r^3} \qquad (4)$$

and

$$R^4 = (0.8)(V_o)(M_b t) \qquad (5)$$

(U) Since not all the air is snowplowed, velocities at the cloud edge may be

$$R^4 = (V_o)(M_b)(t) \qquad (6)$$

or

$$R = \sqrt[4]{V_o\ M_b} \times t^{1/4} \text{ meters} \qquad (7)$$

(U) Since bursting charges used in chemical munitions are usually a small fraction of the total weight, Gurney's law can be rewritten

$$V_o = 2100\sqrt{\frac{M_{ex}}{M_{in}}}\ \text{m/sec} \qquad (8)$$

Combining Eqs. 7 and 8 gives

$$R = \sqrt[4]{2100\ M_b} \times \left(\frac{M_{ex}}{M_{inert}}\right)^{1/8} \times t^{1/4} \qquad (9)$$

(U) Here we have a derivation for the widely observed insensitivity of shell clouds to the burster ratio. Assuming a burster-to-inert-mass ratio of 0.1,

$$R \approx (6.8)\ (0.75)\ \sqrt[4]{M_b} \times t^{1/4} \qquad (10)$$

$$R \approx 5\ \sqrt[4]{M_b'} \times t^{1/4} \text{ meters} \qquad (11)$$

and

$$\dot{R} \approx 1.3\ \sqrt[4]{M_b'} \times t^{-3/4}\ \text{m/sec} \qquad (12)$$

(U) An approximate check with experiment for these formulas is shown in Fig. 1.

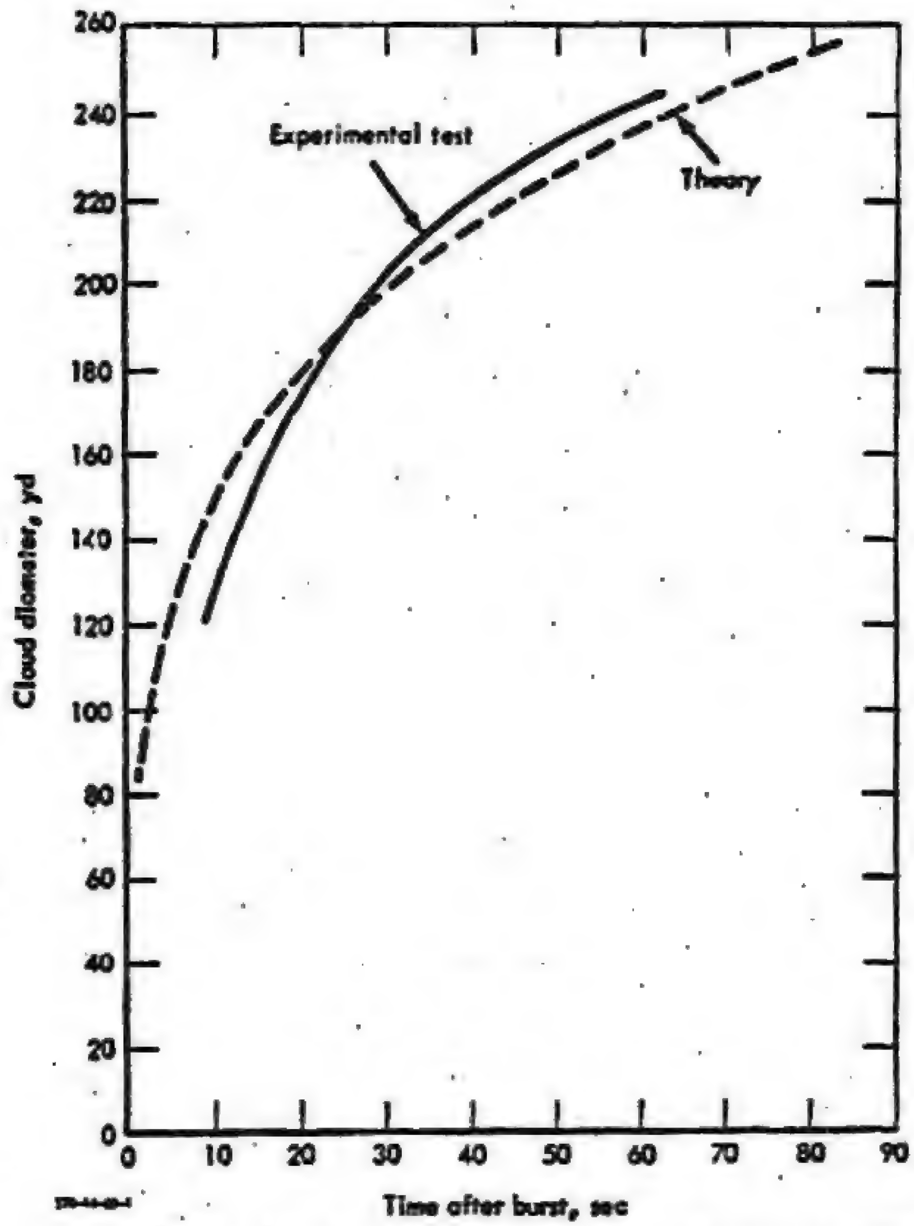

FIGURE 1 (U). Experimental and Theoretical Cloud Diameters for 4000-lb Bombs with Burster Weight One Percent. Test Data from Ref. 2.

(U) For a 1-kg bomblet containing 500 grams of agent:

$$\text{Cloud Concentration} = C = \frac{500{,}000 \text{ mg}}{500\, t^{3/4}} \tag{13}$$

$$\text{therefore,}\quad C = 1000\, t^{-3/4}\ \text{mg/m}^3$$

t in seconds

(U) Note that the concentration is down to 125 mg/m^3 at 16 sec and 45 mg/m^3 at one minute. The German 77-mm Blue Cross shell contained 2 percent DA and should have given concentrations about one-tenth those above, giving doses as follows:

$$\text{Dose} = \int C\, dt = 5t_m^{1/4}\ \text{mg-min/m}^3,\ t_m \text{ in minutes} \tag{14}$$

(U) Therefore, remaining in the cloud from the German Blue Cross shell for 15 minutes might have given a dose of about 10 $mg\text{-}min/m^3$ less than 0.1 percent of the lethal dose, but enough to cause masking. Very likely, the HE fragmentation of this shell caused far more fatalities than did its diphenylchlorarsine. Dosages from this cloud theory agree very well with the field experience* described in the following section.

C. DISCUSSION OF FIELD DISSEMINATION

(U) The wide field experience (Refs. 3 and 4) with chemical weapons has shown that dosage can be predicted in area targets, either open or wooded, to be about:

$$\text{Neutral Atmosphere Dose} = \frac{20}{\text{wind vel in mph}}\ (\text{lb/ha})\ \text{mg-min/m}^3 \tag{15}$$

$$\text{Inversion Condition Dose} = 2\text{x}\ \text{"}\quad (\text{lb/ha})\ \text{mg-min/m}^3 \tag{16}$$

$$\text{Lapse Condition Dose} = 1/4\ \text{"}\quad (\text{lb/ha})\ \text{mg-min/m}^3 \tag{17}$$

*See Appendix A.

For wooded targets, FM3-10B assumes a neutral atmosphere and a 2 mph wind.

(U) Uncertainties in wind, atmospheric stability, and uniformity of dissemination, could each introduce a factor of two, and as these factors may be multiplicative, the resulting dose uncertainty could well be a factor of eight. Therefore, in planning nonlethal attacks, only agents with a safety factor considerably greater than ten between effective and lethal doses should be used.* Nerve gases and phosgene are ruled out on this basis, while tear gas should be (and has proved to be) nonlethal in the open. The 14,000,000 Blue Cross arsenical shells used by the Germans in World War I caused virtually no recorded deaths from diphenylchlorarsine (DA). In the great attack of March 21, the DA expenditure was 40 lb/ha on the infantry belts. With a low wind of 1 mph and inversion conditions, the dose predicted from Eq. 16 would be 1600 mg-min/m^3 for unmasked (and the British were masked) troops--about 10 percent of the lethal dose. The fragmentation from these same shells (equivalent to fifty-five 105-mm projectiles per hectare) could easily have killed or wounded most of the unprotected troops** in the area.

D. WORLD WAR I EXPERIENCE WITH CHEMICAL WEAPONS

(U) The First World War saw one chemical agent after another replaced by superior agents, until the primacy of mustard and phosgene was established by 1918. Quite surprisingly, the introduction of gas masks did not eliminate the toxic gas cloud as an effective war weapon, and the British continued to use gas clouds from cylinders right through 1918. The first chlorine attacks were against totally unprotected troops and were, of course, highly effective, producing a casualty for each 22 lb of Cl expended against the British and 58 lb against

*Project Summit used a safety factor of ten to define nonlethal agents.

**The gas, of course, reached into trenches and gun pits.

the Russians (Ref. 5). The next attack against the British required 94 lb of chlorine per casualty (Ref. 5), presumably because the British has been issued the chemically treated black veil mask to cover the nose and mouth. Yet, the last cloud attack of the war (July 1918), against the best German masks, produced one casualty for every 70 lb of phosgene expended. Since the incapacitating dosages of phosgene and chlorine are about the same,* the inability of good masks to conquer gases easily neutralized in canisters is striking. To the end of the war, gas cloud attacks maintained an average of one casualty for 95 lb of agent, inflicting 105,000 casualties (including 31,750 deaths) with the expenditure of 5000 tons of chlorine, phosgene, and chlorpicrin. A similar performance was achieved with trench-mortar projector attacks. (See Table 2.)

(U) Artillery proved to be a much less efficient delivery means for chemical agents. Individual shells carry too little agent to easily build up a lethal concentration. Nine-tenths of each shell's weight must be inert metal. Thus, one would expect a shift away from lethality for all agents when delivered by artillery, and a shift toward agents (such as mustard) which are effective in low concentrations. Both these effects occurred. Phosgene's lethality dropped from 20 to 30 percent in cloud attacks to about 7 percent in artillery attacks. At the same time, the inefficient, under-dense, artillery deployment raised the agent requirement from 95 lb per casualty to around 340 lb per casualty. Mustard became the preferred fill for shells, and CW fatalities dropped to ~ 2 percent of the chemical casualties.

E. OPERATIONAL RESPIRATORY LETHALITY OF VARIOUS AGENTS

(C) An idealized nonlethal agent would have a saturated vapor concentration (volatility) which is nonlethal but highly incapacitating. An extremely large ratio between lethal and incapacitating concentration is obviously desirable to prevent battlefield variation from

*Contrary to the earlier data available to Prentiss (Ref. 5).

TABLE 2 (U). CASUALTIES FROM MAJOR WORLD WAR I GAS ATTACKS

Type of Delivery	Year	Agent	% Lethal	Protection	Pounds of Gas per Casualty	Comments
Gas Cloud from Cylinders	1915	Cl	33	No masks	22	No masks!
	1915	Cl	5	Cloth pads & veil	94	Too diffuse?
	1915	Cl	25	Against German early masks	60	
	1915	Cl	75	Against German early masks	60	
	1915	Cl	65	Against Russian no masks	50	
	1916	Cl/CG	30	Vs. German - Somme	60	(due to phosgene?)
	1917	Cl/PS	26	Vs. French	395	
	1918	Cl/PS	10	Vs. German	115	
	1918	Cl/CG	7	Vs. German	75	
Projectors	1917	CG	85	Vs. Italian - no masks?	27	(no masks?)
	1917	CG	20	Vs. German - good masks	191	(good masks)
	1918	CG	22	Vs. German - good masks	108	
	1918	CG	22	Vs. German - good masks	162	
	1918	CG	12	Vs. American	43	(green troops)
Artillery	1916	CG	6	Vs. French - (fair masks)	343	(too dispersed)
	1917	CG	11	Vs. French - (fair masks)	225	
	1917	PS	9	Vs. German	500	
	1917	CG	26	Vs. Italian	300	(compare with projectors)
	1918	DA/CG	1.5	Vs. French (DA casualties + dispersal)	600	(DA + diffuse)
	1918	HS	2		500	
	1918	CG	5	Vs. German	400	
	1917	PS	6	Vs. German	400	
	1917	HS	2.5	Britain	340	
	1917	HS	1.1	France	380	

building up a nominally nonlethal concentration into a lethal one. However, it is clearly desirable to have the volatility many times lower than the lethal concentration for times characteristic of combat exposure. As Prentiss points out, "... acrolein and brombenzyl cyanide are more toxic than phosgene, although the volatility of the latter is too low to permit fatal concentration in the field."

(U) Since nonlethality depends on the ratio of lethal to incapacitating concentration and on the relative volatility of the agent, a safety figure-of-merit can be constructed as the product of these two factors, namely,

$$\text{Nonlethality} = \frac{\text{lethal concentration}}{\text{incap. concentration}} \times \frac{\text{lethal concentration}}{\text{volatility}}$$

$$\text{Nonlethality} = \frac{LC}{IC} \times \frac{LC}{V}$$

(U) Concentration will be based on an exposure of ten minutes (as in Prentiss) and volatilities will be standardized at 20°C (68°F), except for low volatility solids. Solid agents will be presumed to be explosively dispensed to give initial cloud concentrations of 100 mg/m^3. Thus, 100 mg/m^3 is the maximum* aerosol concentration and this corresponds to volatility as an upper limit for the nonlethality index.

(C) If the agents in Table 3 are arranged in order of their nonlethality indices, the great spread shown in Fig. 2 is obtained.

(U) One can see how these agents fall into three main classes: those with safety factors in the thousands, a transition group at the threshold of lethality, and a deadly group more lethal than gun and shell injuries. Note that the transition group is distinctly less lethal than gunshot wounds (25 percent fatal). In fact, ethyldichlorarsine

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*Except in the unlikely event of two shells or bombs striking the same place in quick succession.

may be about a hundred times safer as a casualty producer than conventional HE or napalm. Use of Class C agents may well constitute an escalation in an HE war, while the use of Class A agents would appear to be preferable to bullets and be a de-escalation from HE. The position of Class B agents on the scale of escalation is largely a function of propaganda and world opinion. Logically, they are generally more humane than conventional bombs or shells.

TABLE 3 (C). AGENT CHARACTERISTICS FOR RESPIRATORY ATTACK

(Breathing Rate 10 liters/min)

Agent	Symbol	Incapacitation Concentration mg/m³	10-min Lethal Concentration mg/m³	LC/IC	V (Volatility) mg/m³	LC/V	Non-Lethality Index	WWI Lethality, %
Chloroacetophenone	CN	8	1120	140	130	11	1540	Not Used
Bromobenzylcyanide	CA	3	1130	566	110	4	2192	7
"CS"	CS	1-5	11,000	1000	177*	50	50,000	Not Used
Arsenical Riot Agents	DA DC DM	1	1500	1500	100*	15	22,500	~0
Psychochemical	BZ	15	6000	400	100*	60	24,000	Not Used
Bromoacetone	BA	33	3200	110	75,000	0.04	4.4	~6
Ethyldichloroarsine	ED	1	400	400	20,000	2x10⁻²	8	~0.1
Mustard Vapor	HD	20**	150	7.5	610	0.25	2	2
"T" Agent Vapor	T	(~5)	(~120)	(~25)	100* (0.35)	1 (400)	25 (12,500)	Not Used
HN3 Vapor	HN3	20	150	7.5	90	2	15	Not Used
Chlorine	CL	180	1900	11	15,370,000	1x10⁻⁴	1.1x10⁻³	5 to 45
Phosgene	CG	150	333	2	6,130,000	5x10⁻⁵	1.0x10⁻⁴	7 to 95
Nerve Gas	GB	7.5	15	2.11	11,500	1x10⁻³	2.6x10⁻³	Not Used
Nerve Liquid Aerosol (Inhal)	VX	2.2	4.5	2	100* (10)	0.045	0.09	Not Used
Nerve Spray (Percut)	VX	35-133 (mg/m²)	70-1330 (mg/m²)	2	--	--	--	Not Used

*Denotes aerosol concentration controlled by agent-burster ratio.
**Threshold dosage for eye damage = 100 mg-min/m³, and therefore 10-min concentration is 10 mg/m³.

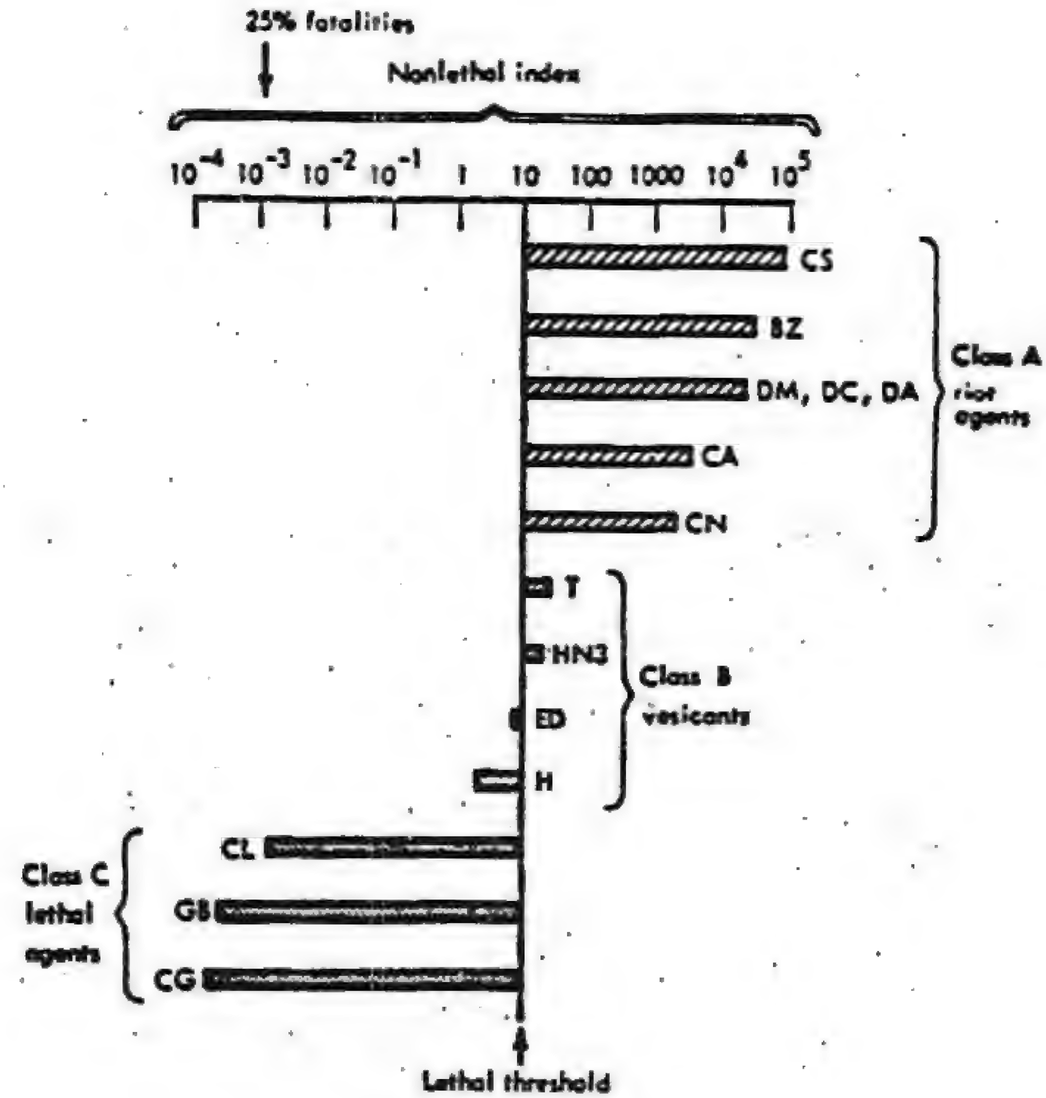

FIGURE 2 (C). Relative Safety of Various Chemical Agents for Incapacitating Attacks. Index Calibrated by World War I Data. (For Practical Purposes Indices Below 10^{-3} Are Equivalent, Providing Sufficient Agent Is Used for Widespread Incapacitation.)

IV. VESICANTS--A SPECIAL CASE

(U) It is rather surprising that the primary blister liquid, mustard, produced most of its casualty effect through vapor attack rather than through liquid percutaneous entry. The reason for this paradoxical behavior is the low German expenditure of mustard per square mile, which left 80 percent to 90 percent of the target area free of contact hazard, while covering most of the area with a vapor dosage insidiously dangerous to unmasked personnel. However, about half of the American mustard casualties also had some skin burns from liquid or vapor mustard.

(U) If the Germans had used T-agent, whose vapor pressure is less than one-thousandth that of mustard, but whose vesicancy is five to eight times that of mustard, then vapor casualties would have been nil and the contact casualties possibly quintupled. Australian tests in jungles showed that even the relatively volatile mustard left a contact hazard after one or two days of evaporation (Ref. 6). T-agent is far more persistent than mustard and should last for weeks.

(U) Area denial should be very effective with T-agent for a number of reasons. Its extreme vesicancy produces an effective contamination of one hectare with only 70 lb of agent. Its persistency reduces the need for frequent renewal. Its near invisibility precludes easy avoidance where areas are only covered in a spotty manner. Thus, living in an irregularly contaminated area would be hazardous because one would sooner or later blunder into a contaminated patch of terrain.

(U) Mustard and the sesqui-mustards are very slow acting. Blisters take many hours to develop, and so these agents are not able to stop an attack in progress. Although the nonvolatile T-agent should cause no deaths from inhalation, death from contact burns is

a possibility. An Edgewood Arsenal estimate for a lethal skin dose of mustard is 7 grams, which would correspond to about 1 gram or 1 cm^3 of T-agent liquid spread over most of the body. The lethal mechanism is similar to third-degree thermal burns. The blister threshold for T-agent is a 4 microgram droplet-- $\frac{1}{25,000}$ of the lethal dose--making it extremely unlikely that a casualty density of T-agent would be lethal.

(U) There is no easy way to live in a mustard environment on a long-term basis, particularly in tropical climes. Gas masks, of course, are circumvented by the percutaneous attack. Completely mustard proof clothing (gloves, boots, hoods, etc.) is practically air-tight and thus intolerable in the tropics. The following time limits are recommended for moderately active men in U.S. impermeable decontamination outfits:

Temperature, °F	Maximum Time in Suit, hr
< 30°F	8
60-70°F	2
90+°F	1/4

(C) So-called impermeable materials are far from perfect and really only delay penetration. Neoprene and natural rubber only block mustard for 10 or 15 minutes in thin (0.4-mm) layers (Ref. 6). Mustard soaks through leather rapidly. Butyl rubber is much better; a 0.4-mm layer protects for over two hours.

(C) Chlorinated ointments and light impregnated clothing provide substantial protection and can be worn for at least three days. The protection factor nominally appears to be from 20 to 50, providing the ointment is not rubbed off (Ref. 6). In practice, however, exercising men suffered severe hand burns from vapor at 1000 mg-min/m^3. Some moderate burns appeared elsewhere. As the threshold for moderate burns is about 200 mg-min/m^3, the apparent protective factor under working conditions may only be about five. Possibly the preferred

counter to sesqui-mustards would be moderate personal protection by impregnated clothing, disposable gloves, ointment, and masks until chemical decontamination squads could neutralize the areas which must be inhabited--all of which would be difficult for guerillas.

(C) Decontamination may be impractical on any large scale for all but first-class industrial powers because demustardizing requires about 20,000 lb of evenly distributed bleach slurry for 1 hectare. Prentiss (Ref. 5) points out that "decontamination in a wooded area is much more difficult than in the open and is only feasible when the extent of contamination is slight. The degree of contamination cannot be gauged entirely by the number of shell holes on the ground, since shells frequently strike and explode in the tops of the trees, sprinkling them with droplets of mustard ...." Wood and concrete absorb mustard gas, and if left untreated, become permeated and very difficult to decontaminate. Therefore, buildings and factories, when grossly contaminated, "should be disposed of by burning if this can be done with safety." Burning, of course, produces a highly toxic, mustard-laden smoke. The potential to contaminate dock areas, warehouses, munition factories, and SAM sites might be of major importance.

V. OPERATIONAL APPLICATIONS

(U) Having summarized the properties of the various existing chemical agents and having examined their general dissemination and effectiveness characteristics in the field, we now address more specifically the operational applications of chemical weapons under intermediate war conditions.

A. CHEMICAL BARRIERS

(C) Chemical barriers can be formed by contaminating terrain and vegetation with vesicants, HD, and T-agent. However, contact with the CW agent has to be insured. Contaminated jungle foliage will brush against traversing troops. Suppressive fire will drive infiltrating troops to earth, as will barbed wire and minefields. Any T-agent coated obstacle, such as a ravine, cliff, or bomb crater, that must be scaled or crawled over will cause eventual casualties. As T-agent is nonvolatile, it should persist for a month or so and still not present a vapor hazard or a downwind hazard. T-agent barriers could, therefore, be well defined and carefully positioned away from civilians. It is well to note that vesicant barriers are complementary to conventional interdiction, since they work best in heavy jungles and on narrow trails, where the enemy has maximum concealment from HE and cannon attacks. T-agent barriers, on the other hand, are least effective on open, undamaged highways where trucks can move rapidly over them. Table 4 summarizes the requirement for forming chemical barriers with various agent.

(C) Siliconized CS and DC powders can provide a persistent aerosol hazard because silicon-coated 5μ particles are readily stirred up into a dusty cloud by any motion in the area. Persistence in the damp soil of tunnels has been 30 to 60 days for CS_a.

TABLE 4 (C). BARRIER AGENT REQUIREMENTS

Agent	Type of Hazard	Duration	Pounds/ha	Pounds/ha/day
T	Contact	2-4 weeks	~ 100	~ 5
CS Alpha	Inhalation	1-2 weeks	~ 600(?)	~ 60
DC (Silicon)	Inhalation	1-2 weeks	~ 150(?)	~ 15
Mustard	Vapor and Contact	3 days	~ 600	~ 200
CA	Inhalation	~ 1 week	~ 400	~ 50

(C) Barrier width is a flexible parameter. The chemical hazard is proportional to the product of the width and the contamination density (Ref. 7). The chemical pickup from crawling over short grass or walking through dense shrubbery and tall grass is about 3.5 mg/m times the contamination density of grams/m^2. If the incapacitating contamination of mustard is 500 mg on clothing, then crawling 150 meters over ground contaminated by 1 gram/m^2 of H would result in a delayed casualty, unless complete changes of clothing, gloves, and boots were immediately available. Hands are particularly likely to pick up mustard, so crawling in mustard areas without gloves would result in serious (although delayed) burns from contamination acquired in a few minutes.

(U) Since the chemical pickup varies as the product of barrier width times the concentration, the amount of agent required per unit barrier length is an invariant (see Table 5).

(C) Effective duration times are rather uncertain, as they are quite dependent on terrain, soil, vegetation, weather, and deposition characteristics. Only mustard data are available; corresponding values have been extrapolated for T-agent and HN3. VX is a different type of chemical and apparently decays primarily by absorption rather than evaporation. However, on the above basis, one B-52 could establish a T-agent barrier the whole length of the Vietnam DMZ (65 km) in one sortie.

TABLE 5 (C). VESICANT AGENT REQUIREMENTS PER UNIT LENGTH OF BARRIER

Agent	Type of Hazard	Effective Pickup Dose, mg	Agent Needed, kg/km	Volatility at 25°C, mg/m³	Time for 3/4 to Volitalize
T	Contact (Incap)	100	300	0.4	3 week (+)
H	Contact Vapor	500	1500	960	2-20 hr (Ref. 3)
HN3	Contact (Incap)	700	2100	120	15 hr to 1 week

(C) Trail denial involves a barrier which is coaxial to--rather than across--the line of march. Contamination densities could, therefore, be considerably reduced for narrow trails where troops must brush against foliage or grass. As little as 300 lb of T-agent per kilometer might be effective. Wider trails and roads, however, would be difficult to block with nonvolatile T-agent, although bivouac areas and truck parks would be prime targets for T-agent attacks. A combination of T-agent and CS_a attacks probably would seriously hamper the access routes to a battle area.

B. AIRCRAFT PAYLOAD COVERAGE

(U) The combined effect of increased bomber payloads (B-52) and the heightened toxicity of modern CW agents is to confer a surprising area coverage to a modest sortie rate. This quantum jump in efficiency can be seen in Table 6.

TABLE 6 (C). ADVANCES IN CW MUNITIONS

Era	Agent	ID_{50}	Munition	Weight, lb	Agent wt, lb	Efficiency, %	Area Coverage, ha
WW I	CG	1600	15-cm shell	72	10.6	11	0.033
WW II	CG	1600	500-lb bomb	500	200	40	0.66
1965	GB	35	Weteye bomb	562	347	62	35.0

(C) The numbers shown in Table 6 are for standard conditions of 4 to 5 mph winds, neutral temperature gradients, and temperatures sufficient to vaporize the agents rapidly (i.e., above 30°F). The gain in area coverage is a thousandfold since World War I.

(C) If the 50,000-lb payload of a B-52 were devoted to CW munitions with an agent fill of 50 percent, then the optional capabilities in Table 7 would be available.

TABLE 7 (C). B-52 CW AREA EFFECTIVENESS

Agent	Dosage	Deposition Density, lb/ha	Area Covered By One B-52, ha	Chemical Persistence	Casualty Effect
CS	20 mg-min/m³	5	5000	Cloud Transit	Tearing, coughing, chest tightness—10 min.
DC,DA,DM	20 mg-min/m³	5	5000	Cloud Transit	Sneezing, pain in head and chest, nausea—1-2 hours
BZ	120 mg-min/m³	30	830	Cloud Transit	Hallucinations after 13-12 hours lasting 3 to 7 days; fatigue
CG	100 mg-min/m³	25	1000	Cloud Transit	Burns eyes, throat, bronchi, lungs; choking and asthma for 4 to 72 hours
HD	Contact Hazard	120	50	3 days	Delayed skin burns lasting 6 weeks.
T	Contact Hazard	120	250	3 months?	Delayed skin burns lasting 6 weeks.
GB	80 mg-min/m³	20	1250	Cloud Transit	Fatal in 1 to 10 minutes.
VX Aerosol	60 mg-min/m³	15	1700	Cloud Transit	Fatal in 1 to 10 minutes.
VX Spray	Direct-Deposition	1.6	27,000	—	LD_{50} for summer clothing.
VX Spray	Direct-Deposition	20	1500	—	LD_{50} for winter clothing.

(C) The scale of these areas can be appreciated by noting that a 155-mm high explosive shell has a lethal area of 1000 m^2 against standing troops and 300 m^2 to 700 m^2 against prone troops. The BLU-26/B is ten times as efficient against troops in open terrain, and 100 lb per hectare are needed. British data suggest that entrenched troops cannot stand artillery attacks for more than 5000 lb per hectare in a 4-hour period. Hiroshima's 15-kt atomic bomb was effectively destructive over 8 km^2 or 800 hectares. It is striking to note that

six of the eight chemical payloads in Table 7 exceed the 15-kt bomb used at Hiroshima in area of weapon effect. A graphical comparison of weapon coverage is shown in Fig. 3.

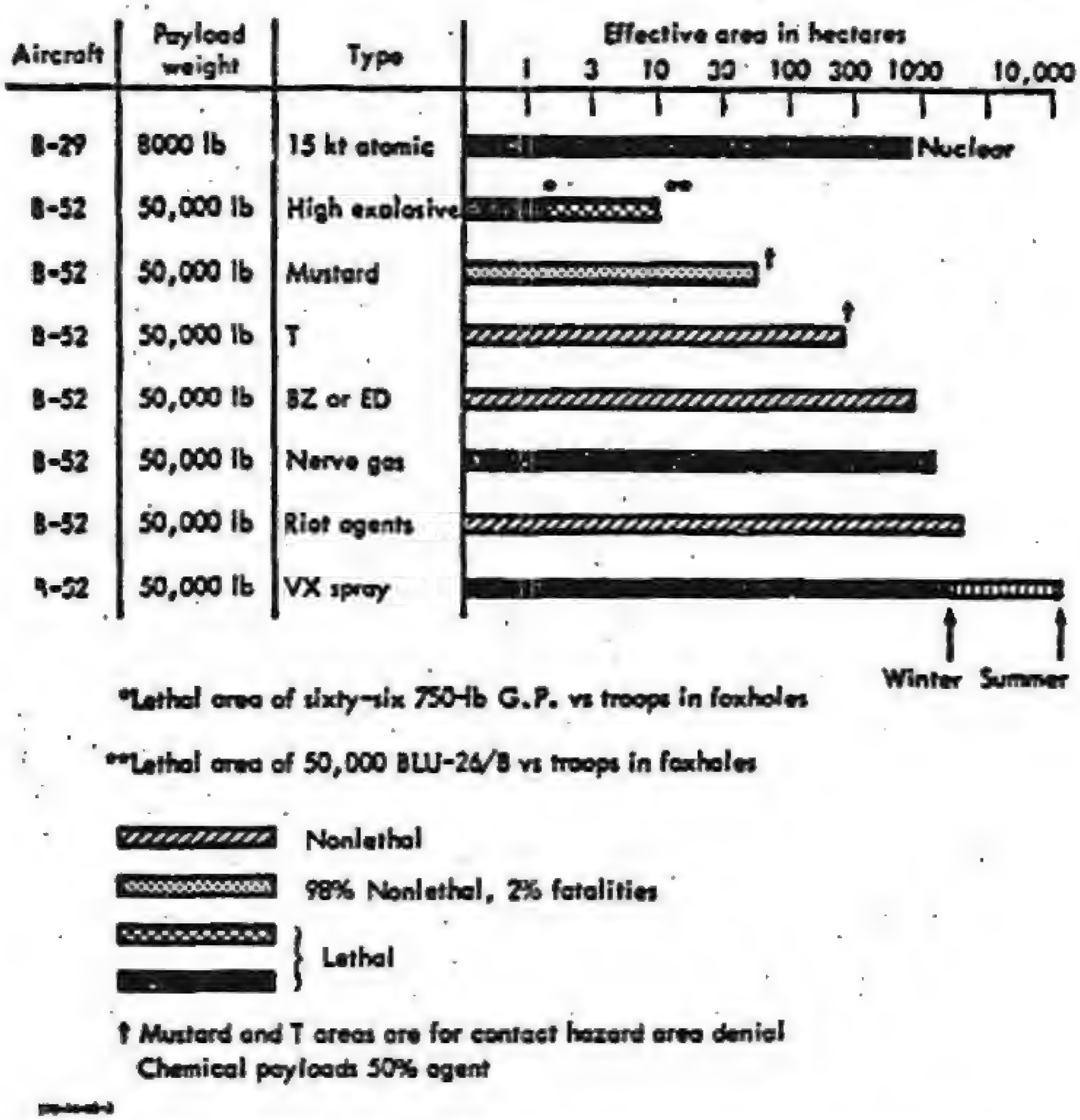

FIGURE 3 (C). Effective Areas of CW and HE Payloads Compared to Hiroshima 15 kt Atomic Devastated Area

(C) Despite the diversity of weapons effects, there are some common denominators. Practically all people in blast shelters (providing they are gas-proof) could survive any of the above attacks (although prolonged HE attacks of this density may produce mental collapse as well as physical destruction). All attacks, except T-agent and HD, could be thwarted by prior evacuation and rapid reoccupation. Evacuation of areas the size of the District of Columbia (15,000 ha) is, of course, much more difficult than side-stepping the cloud from a burning CS grenade. Thus, while the toxic effect of CS may only last a few minutes, the escape and reoccupation times necessary to thwart a BZ or GB attack may total a few hours.

C. EFFECTIVENESS OF RESPIRATORY ATTACK

(C) Unmasked troops and supply columns can be expected to be completely neutralized by CS-DM attacks, provided the agent clouds are replenished frequently enough. A period of enemy troop paralysis would ensue until masks could be provided. A four-week interruption of Red infiltration would have unknown consequences on the Vietnam war. Major area saturation with CS-DM would be a tactic (like the first German chlorine attack) that possibly could be used only once in a decisive way.* A large force might be encircled by a CS-DM ring, and then incapacitated and captured. The enemy would probably try to remain dispersed until masks were obtained. Massive search and destroy operations could be instituted under the protection of the irritant clouds during this interval.

(U) Modern masks provide at least a thousandfold protection,** so the dominant influence of CS would change from troop incapacitation to the troop harassment caused by continuous masking when good masks are provided.

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*However, Dorothy Kneeland Clark points out five chemical breakthrough attacks in World War I.

**Under ideal conditions.

(C) A lumped parameter for the loss of working efficiency caused by the physiological burden of a gas mask has been set at about 15 percent (Ref. 6). Another 15 percent of the troops may become casualties from poor fitting of masks. Thus, a 25 percent to 30 percent loss in short-term capability may be expected against nominally masked troops. In addition, prolonged gas threats will invoke further reductions in efficiency because:

1. A man cannot eat, drink,* smoke, vomit, or blow his nose while masked.
2. While sleeping, a mask may be pushed off.
3. Vision is reduced by the lens field and by scratches, dirt, and fog on the lenses. Telescopes and other optical instruments are hard to use because of the standoff of the lenses.
4. Dissipation of body heat is hindered, which increases the heat burden in the tropics.
5. Facial skin infection can become a problem.
6. Torn or damaged masks can be expected during prolonged use.
7. Voice communication is hindered.*
8. Premature unmasking may cause casualties.
9. Failure to mask soon enough may be fatal or incapacitating.

(U) The last two factors each accounted for about 25 percent of the AEF gas casualties in World War I. These American data reflect the insidiousness of mustard gas, which could not be smelled in low, but incapacitating concentrations. The percentages of masking failure were naturally different for surprise phosgene attacks, which were anything but insidious. Table 8 gives World War I statistics on projector attacks with phosgene.

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*A few masks allow drinking and voice communication.

TABLE 8 (U). REASONS FOR CASUALTIES FROM PROJECTOR ATTACKS
(Ref. 8)

Reason	No. of Casualties
1. Slow Masking	
a. Surprised when drums landed	500
b. Unexpected cloud drift	340
2. Surprised or Masks Lost or Defective	1100
3. Failure to Mask	
a. Asleep	191
b. Wakened and could not find mask	79
c. Direct hits (wounded or immediately overcome)	532
4. Mask Penetrated	62
5. Premature Unmasking	29
TOTAL	2833

(U) Among nominally mask-equipped troops, U.S. field manual FM-3-10 estimates ~ 50 percent casualties from surprise attacks on troops under major stress from exertion, fatigue, temperature, attack, or mental stress.

(U) Troops engaged in normal, mild activity would suffer 25 percent casualties from a surprise chemical attack, while troops under favorable conditions would suffer 10 percent casualties.

D. OPERATIONAL EXAMPLES

1. Haiphong

(S) A harrassing attack on Haiphong is depicted in Fig. 4. A bolt of CS bomblets 5 km long and 1 km wide was presumed laid across the dock areas. The density of deposition was 10 lb/ha, and so only 5000 lb of agent were expended. With a 5-mph wind from the north, a target area dosage of 40 mg-min/m^3 was anticipated in the target area. A more detailed application of the formulas in TM3-200 shows a target dosage rising from 30 mg-min/m^3 on the upwind side to 70 mg-min/m^3 on the downwind side. The 20 mg-min/m^3 contour extends downwind 1.3 km from the target; the 10 mg-min/m^3 contour reaches 3.8 km downwind; and the 5 mg-min/m^3 dosage drifts 9 km. The time of passage of the cloud would be about 10 minutes; therefore, the dosage contours in Fig. 4 represent about ten times the airborne concentrations.

(S) CS is generally considered intolerable in concentrations of 1.5 to 2 mg/m^3 and distinctly harrassing down to a concentration of about 0.7 mg/m^3. Experience in World War I and civilian riot data shows that people will run away from irritant windblown clouds. With a 5-mph wind, the Haiphong residents could escape from the CS at a rapid walk. The result, then, of this light attack would only be the harassment and temporary dislocation of the population of this seaport. No prolonged incapacitation would be expected. Work might be stopped for 20 minutes to 2 hours, depending on whether or not the workers fled to open country. Repeated raids might result in varying degrees of evacuation, since CS victims are generally considered highly reluctant to face repeated doses. Such harassing raids would be a step toward the Clauswitzian principle that "we must place (the enemy) in a situation in which continuing the war is more oppressive to him than surrender."

(S) If 10,000 lb of diphenylchlorarsine were used in place of the CS, concentrations in the target area would exceed 10 mg/m^3. Wachtel (Ref. 1) reports that 2 mg/m^3 is intolerable within 1 minute, and that a 2-minute exposure to 10 mg/m^3 causes vomiting, coughing, and pain in the forehead, ears, and chest, followed by dyspnoea and depression.

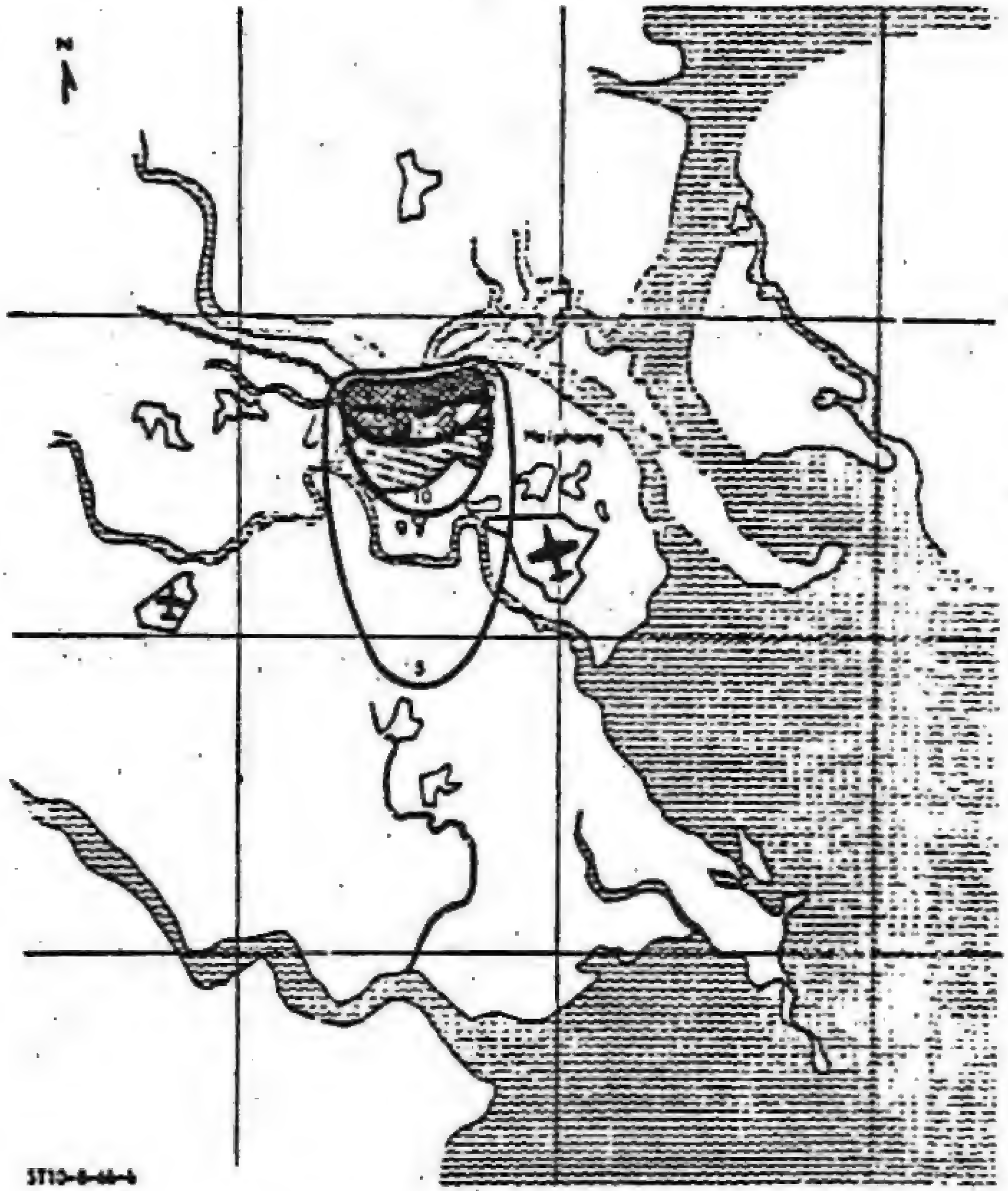

FIGURE 4 (C). Hypothetical Chemical Attack on Haiphong. 5000 lb of Agent Deposited in 1x5 km Strip. Wind from the North at 5 mph; Lapse Rate Neutral.

Since the after-effects may last 10 or 20 hours, a single raid might disrupt a city for a full day, unless masks were widely available.

(S) If 10,000 lb of GB were dispersed under these conditions, the whole 5-km^2 target area would be within the lethal contours, and hazardous dosage might extend 15 km downwind.

(S) An often heard question is whether atmospheric variability makes dosage contours too erratic to predict. If one assumes Clark Field weather is typical of the South China Sea area, then we note lapse conditions apply only 4.2 percent of the time and winds over 8 mph occur about 1.4 percent of the time. This would indicate that target dosages would be within a factor of two of those shown in Fig. 4--82 percent of the time--even if synoptic weather data were not used. Such pattern stability does not apply to isolated point sources, but it is a result of the law of large numbers in an array of bursting munitions. This stability of numerically large arrays has long been noted in fallout calculations.

2. Hiroshima

(S) The strategic nuclear attacks on Hiroshima and Nagasaki are widely credited with terminating World War II. Most of the destruction and deaths occurred within 1 mile of ground zero. As Fig. 5 shows, 25,000 lb of nerve agents would have produced a more extensive lethal area with the meteorological conditions prevailing at 08:17 on the 6th of August 1945. The direct comparison of LD_{50} contours is, of course, a considerable oversimplification if protective measures are available to the target population. The LD_{50} radius for people in concrete buildings (not in shelters, but merely in concrete buildings) was only 0.12 miles. The LD_{50} radius outdoors was 1.3 miles. Against a GB attack, masking within 30 seconds would reduce the LD_{50} area to 2.5 km^2. At 60 seconds, the LD_{50} contours would only cover the 5-km^2 target area. Most of the windows within the target area would be broken by bomblet explosions, although such breakage may not be essential to the attainment of serious indoor gas dosages. Tests have shown that mustard penetrates mine tunnels by normal circulation to a remarkable degree; underground doses frequently approximate the exterior dosages.

(S) ~~Some~~ variations of fatalities with protection at Hiroshima are estimated in the following table:

Weapon	Protection	Fatalities
15 kt	Random	68,000 (actual)
15 kt	Concrete buildings	~ 1,300
GB or VX aerosol	None	~ 100,000
GB or VX aerosol	30-sec masking	~ 25,000

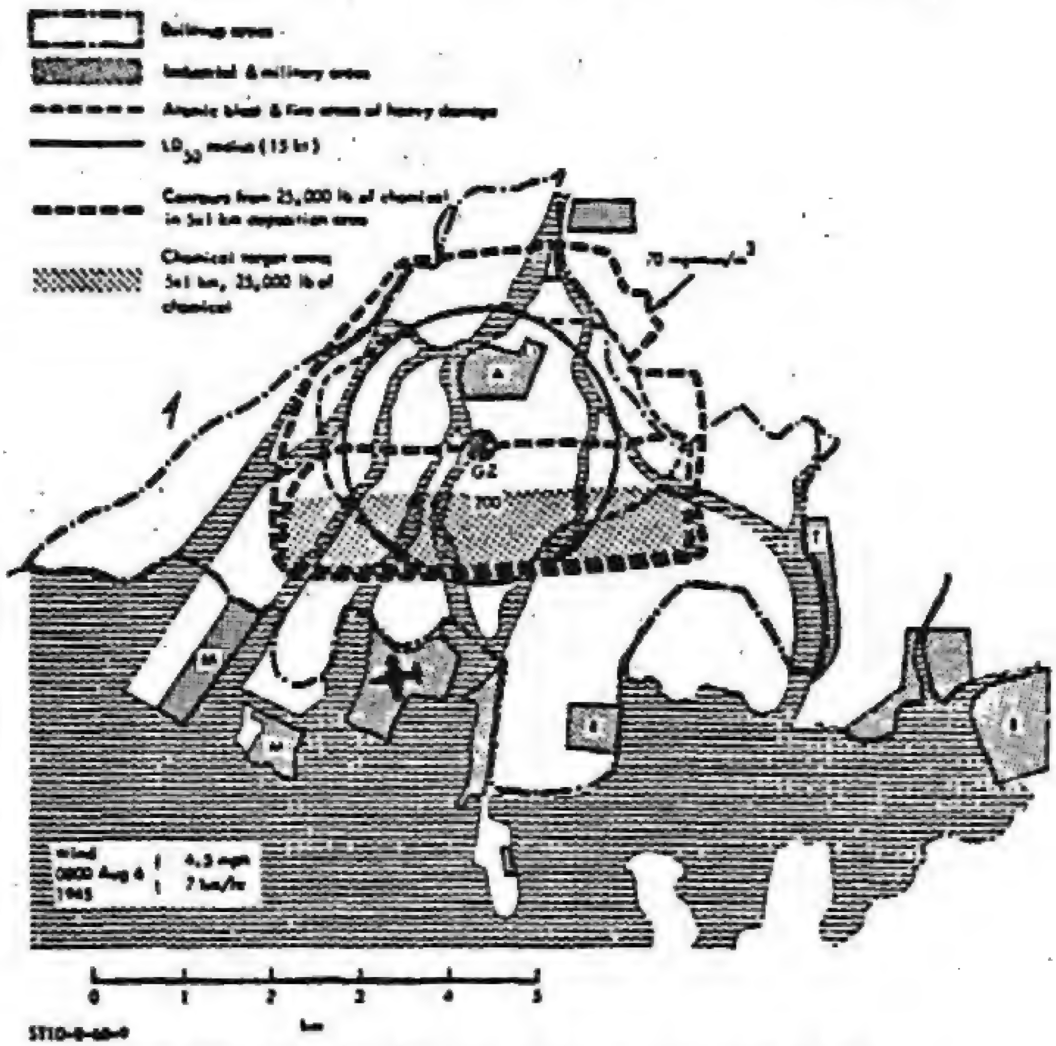

FIGURE 5 (C). Hiroshima Under Nuclear and Chemical Attack

VI. DISCUSSION

(C) The variety of chemical options may be summarized as follows:

3 orders of lethality (~ 0%, ~ 1%, 25%)
3 orders of coverage/lb (10X, 100X, and 1000X HE)
3 orders of persistence (1 hour, 1 day, 2 weeks)
4 orders of duration of incapacitation (10 min, 100 min, 1 day, 6 weeks)
3 types of attack (eyes, respiratory, and percutaneous)

(C) Of course, the 324 cells in this matrix are not all occupied by a specific chemical, but the variety is still far-ranging. Beginning with the three ranges of lethality, it is clear that we have two steps on the escalation scale below the 25 percent conventional HE lethality. The third range, nerve gases, represents a higher level of escalation than HE--not because of a higher fatality rate, but because of greater coverage per pound and the greater downwind hazard of GB. Still, it is in the dimension of time that the chemicals have their most unique contribution to make.

(C) Persistence in time of the sesquimustards suggests the denial of the dock areas of Haiphong, the contamination of transshipment areas of both railroads and trucks, and the blockade of major infiltration routes. Contamination of machinery, trucks, river boats, truck parts, food, guns, and ammunition could put an immense burden on the already taxed North Vietnam supply system. Repair of contaminated bridges, pontoon bridges, factories, roads, and power plants would have to await elaborate decontamination measures. Viet Cong attacks on Saigon and Hue obviously call for CW employment in place of gunfire, rockets, and flame. Both civilians and buildings would be saved by

the use of heavy clouds of nonlethal chemicals. The success of DM against the Korean POW riots is indicative.

(C) Viet Cong sanctuaries, such as Zone D, are natural candidates for area denial. Either the low-volatile vesicants or the siliconized riot agents could be used.

(C) Barbed wire and mine barriers would be extremely hard to penetrate if they were heavily coated with T-agent or mixed with mines containing VX or T-agent. A mixed chemical and HE minefield can be just as well delineated and marked for civilian safety as an ordinary minefield.

(C) Barriers can, of course, prevent escape as well as prevent entry or infiltration. The possibility of trapping a major portion of North Vietnam divisions by chemically blocking escape routes appears very attractive when coupled with an all-out chemical incapacitation attack. The sudden capture and elimination of the bulk of the North Vietnamese armies might be possible by a sudden massive employment of nonlethal chemicals before the North Vietnamese could obtain masks and other chemical protection. The tide of an entire limited war might be turned by the sudden exploitation of chemicals--just as the Germans might have won WW I by complete exploitation of their chlorine breakthrough.

(C) Even without a decisive victory, the use of chemicals might reduce the cost of combat dramatically. For instance, truck destruction by ROCKEYE II bomblets requires 4750 lb/ha, while 10 gm/m^2 of vesicant spray would seriously contaminate both trucks and cargo with an expenditure of 220 lb/ha.* The 60,000 tons expended by B-52s around Khe Sanh in 1968 might have been replaced by a few thousand tons of chemicals--perhaps a ten- or twenty-fold reduction in sorties. Pressure against North Vietnam could be maintained by relatively light raids with CS_{α}, BZ, DC', or T-agent. The reduction in U.S. effort

*The relative ease of truck decontamination versus truck repair is uncertain.

would include not only airpower but also the number of ground troops, since chemically equipped troops are considerably enhanced in fighting power, as German mustard gas employment showed in 1918.

(C) It might be argued that CW will also be used by North Vietnam. But with his limited payload delivery capability, the enemy would have to escalate to nerve gas to achieve any effectiveness. But escalation to nerve gas would seem to be suicidal for a country without air superiority and without lavish chemical defenses and medical resources. Escalation to nerve agents on our part would further reduce U.S. sortie requirements in North Vietnam for a given damage level.

VII. CONCLUSIONS

(C) The following conclusions regarding the use of chemical weapons to perform strategic interdiction missions apply generally to any limited war conditions. However, conclusions 5 through 9 apply specifically to the Vietnamese war.

1. Several CW nonlethal agents offer a major extension of air-power's ability to deny areas that are either too large for HE coverage or are proscribed for fear of civilian casualties.
2. Both lethal and incapacitating chemical payloads can give a single B-52 an effective weapon area coverage greater than the atomic bomb used at Hiroshima.
3. There are indications that costs of U.S. military effort might be markedly reduced (for a given degree of effectiveness) by the extensive use of either nonlethal or lethal chemicals. This area of cost should be more thoroughly investigated.
4. Strategic interdiction chemical attacks would enhance our air superiority and would be difficult to counteract for an enemy without air and technological superiority.
5. CW barriers could restrict infiltration across the DMZ and the Laos-Vietnam border.
6. The Ho Chi Minh Trail might be seriously restricted by non-lethal agents--particulary the nongaseous liquid vesicant T-agent.
7. Jungle sanctuaries, such as Zone D, could be neutralized, and the Viet Cong now there could be driven out by nonlethal agents.

8. Major Viet Cong units could be isolated and defeated by nonlethal ring and area attacks.
9. Haiphong harbor and other transshipment ports could be largely disabled by nonlethal agents.

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APPENDIX A

COMPARISON OF CLOUD THEORY WITH EXPERIMENT

(C) As a check of Eq. 8, a theoretical calculation can be made of a Livens projector shoot at the British test facility at Porton. Equation 8 predicts a radius versus time for a Livens shell as shown in Fig. A-1. The corresponding agent concentration is also plotted.

(C) At Porton, the Livens shells hit, on the average, 12.5 m apart. Thus, from Fig. A-1, overlapping of clouds started by 10 sec. The transit time of the cloud was about 70 sec, so the average height of the cloud (assuming surface bursts) was about 16 m, the same as the average radius from 10 to 70 sec. Since 18.5 gm/m^2 of agent were released, the average concentration from 10 to 70 sec was about 1000 mg/m^3, given a dose of 1000 mg-min/m^3.

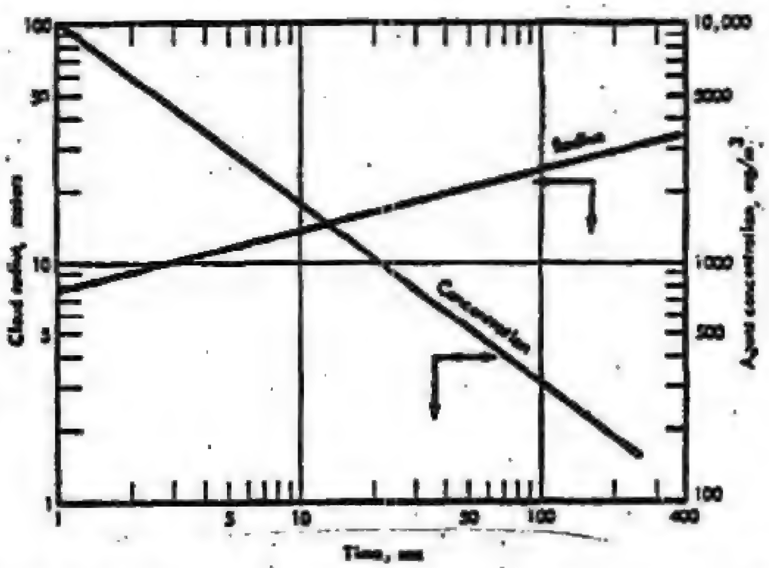

FIGURE A-1 (C). Calculated Livens Projector Cloud Expansion and Concentration

(C) Prior to 10 sec, the concentration varies as $\frac{1}{R^3}$ because there is no overlap. Using Eq. 8 for R, one can derive equations for the concentration (C) and dose (D) as follows:

$$\begin{cases} C = \text{Concentration} = \dfrac{\text{mass of agent (mg)}}{4/3\ \pi\ R^3} \\ \therefore C = \dfrac{(12 \text{ to } 14) \times 10^6 \text{ mg}}{4\ R^3} \end{cases} \qquad \text{(A-1)}$$

(C) For a Livens projectile,

$$M_b = 28 \text{ kg} \qquad M_{ex} = 0.1 \text{ kg}$$

$$M_{agent} \approx 13.6 \text{ kg}$$

$\therefore$ from Eq. 8

$$R = \sqrt[4]{2100} \times 28 \times \left(\frac{1}{280}\right)^{1/8} \times t^{1/4} \text{ by Eq. 8} \qquad \text{(A-2)}$$

$$\therefore R = 15.5 \times \frac{1}{2.04} \times t^{1/4} = 7.6\ t^{1/4} \text{ meters} \qquad \text{(A-3)}$$

$$\begin{cases} \therefore \text{Concentration} = \dfrac{1360 \times 10^4}{1300}\ t^{-3/4} = 10{,}000\ t^{-3/4} \\ \therefore C = 10{,}000\ t^{-3/4} \end{cases} \qquad \text{(A-4)}$$

$$\text{And dose} = D = \int C\ dt = 40{,}000\ t^{1/4} \text{ mg-sec/m}^3 \qquad \text{(A-5)}$$

(C) After the burst clouds start to overlap at 10 sec, the concentration will only decline as $t^{-1/4}$

$\therefore$ For $t > 10$ secs

$$C = 1800/\left(\frac{t}{10}\right)^{1/4} \qquad \text{(A-6)}$$

$$\text{And dose} = D = \int_{10}^{t} C\,dt = (4300\ t^{3/4} - 2400)\ \text{mg-sec/m}^3 \qquad \text{(A-7)}$$

(C) Total dose from 0 to 70 sec for (areas in the cloud at 1 sec) now becomes from Eqs. A-5 and A-7.

$$\text{Total Dose} \sim 1170 + 1300 = 2470\ \text{mg-min/m}^3 \qquad \text{(A-8)}$$

(C) But during the first few seconds, only about two-thirds of the area is covered by clouds, therefore, an average dose for the whole area could be:

$$\text{Dose} \sim 800 + 1300 \sim 2100\ \text{mg-min/m}^3 \qquad \text{(A-9)}$$

(C) The measured dose at Porton was about 4500 mg-min/m^3 (or twice the preceding derived value), but it must be remembered that the theoretical model assumes spherical symmetry, while surface bursts are hemispherical with most of the volatile agent <u>not</u> retained in the ground. The net effect would be to double the dosage, giving very good agreement with the Porton measurements.

(C) Equation 16, however, predicts a dose of 2160 mg-min/m^3, which is very close to the unmodified theoretical value derived on pages 41 and 43.

APPENDIX B

HAZARD FROM COMMON TOXIC CHEMICALS AND RIOT CONTROL AGENTS

(C) The following table presents the hazards to be expected from the deployment of various toxic chemicals and riot control agents. Note that for short exposures, the riot control agents are no more toxic than ammonia or hydrogen sulfide.

Agent	Lethal in Short Time ~(3-5 min)	Lethal (30-60 min)	Prolonged Safe Level	Reference
Phosgene	1000 mg/m^3	100 mg/m^3	4 mg/m^3	Lange's Handbook Chemicals
Chlorine	3000	200	3	
Carbon Monoxide	10,000	2000	400	
Ammonia	6000	2000	60	
Gasoline	20,000	13,000	--	
DM,DA	5000	500	<0.1	TM-3-215
CO	--	4600 (1 hr)	110(8 hr) 460(1 hr)	Wachtel: Chemical Warfare
Hydrogen Sulfide	1400	700-1000	280(1 hr) 14-20(6 hr)	
Hydrogen Cyanide	300	--	--	
CS	20,000	2000-4000	<0.7	Science Journal
Alcohol	10 oz	10 oz	1/2 oz/hr	Note small safety factor

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Strategic Chemical Weapons in Intermediate War (U)

Research Paper P-445, November 1968

Benson L. Tucker

November 1968	43	8

DAHC15 67 C 0011

Task T-7

P-445

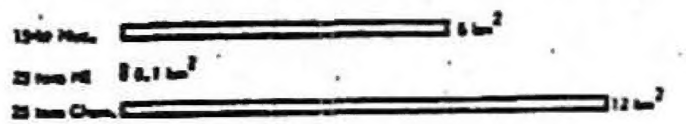
None

In addition to security requirements which apply to this document and must be met, each transmittal outside the Depart- of Defense must have prior approval of Director, ARPA/TIO

NA

Advanced Research Projects Agency, Washington, D.C.

(C) Both chemical weapons, both lethal and nonlethal, [illegible] effective casualty area the first atomic bomb dropped on Hiroshima.



Incapacitation times range from ten minutes (?) to six weeks (?). Areas may be denied to enemy habitation for an agent expenditure of about 1 gm/m² per day. Chemical barriers might severely restrict infiltration and the use of the Ho Chi Minh Trail, Haiphong harbor, and [illegible] sanctuaries. Targets now exempt from HE attack might be neutralized by chemical incapacitating agents. Fighting in or near South Vietnamese cities or villages should utilize incapacitating agents to the fullest to spare civilians.

(C) The cost to the United States of waging intermediate war might be sharply reduced through the use of nonlethal chemicals without escalating the war, conferring a major advantage to the holder of air superiority, while the guerrilla forces would be unable to reply in kind with any effectiveness. The use of nerve agents, on the other hand, would constitute an escalation of conventional war to a realm of lethality intermediate between HE and nuclear weapons. Kiloton effectiveness is achievable without crossing the nuclear bridge.

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